Clinical study

Percutaneous flexor tenotomy for preventing and treating toe ulcers in people with diabetes mellitus

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Keywords
Diabetes mellitus; Tenotomy; Neuropathic ulcers; Diabetic foot wounds; Ulcer prevention; Claw toe/hammer toe; Foot surgery

Abstract
Introduction: The purpose was to examine the effectiveness of flexor tenotomy in a modified technique to prevent and heal neuropathic and neuroischaemic pressure ulcers on the tip of the toe in claw- or hammer-toe deformities in people with diabetes.

Patients and methods: A consecutive 4 years series of 38 patients was retrospectively studied. Percutaneous tenotomy on the superficial and deep flexor tendons was performed in 65 toes through a small transverse plantar stab incision just proximal to the web level. There were 16 (42%) patients with 27 ulcerated toes and 22 (58%) patients with 38 toes with impending ulceration. Ten patients had neuropathic ulcers and six patients had neuro-ischaemic ulcers. Sixteen patients (42%) had macrovascular disease. Ten (26%) had proliferative retinopathy, 7 (18%) macroalbuminuria and 18 (47%) microalbuminuria.

Results: All surgical incisions healed uneventfully. Twenty-five (93%) of the toe ulcers healed in median 21 days (range 7–224 days). Three patients had recurrence of the ulcer. There were no infections in the incisions or toe amputations. No patients treated with preventive tenotomy experienced toe ulceration. No complications were recorded in neuro-ischaemic ulcers. During the follow up period of median 31 months (range 2–48 months) 33 other ulcers were recorded in 18 patients (47%). One of these developed a transfer ulceration under the adjacent metatarso-phalangeal joint and another had a late pressure ulcer on a neighbouring toe. The other 31 ulcers were not related to ulcers treated with tenotomy.

Conclusion: Tenotomy is a simple, safe and effective procedure for preventing and treating distal plantar neuropathic toe ulcers in claw toe or hammer toe deformities in people with diabetes with or without serious co-morbidity. The results suggest that tenotomy should be considered also in neuroischaemic ulcers.

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Introduction

In seven patients with diabetes mellitus will develop foot ulceration [1]. Ulcerations are often difficult to treat, are associated with a high risk of infection and subsequent amputation and are costly for the society [2,3]. Diabetic foot ulcers are associated with a major loss of health related quality of life. The impact of foot-ulcer induced morbidity limitations decreases the quality of life for both patients [4–6], and their caregivers [7]. The 5-year mortality has been reported to be up to 50% [8]. Diabetic foot ulcers can be linked to more risk factors: almost all patients with ulceration have peripheral sensory neuropathy as well as motor neuropathy. A considerable number of patients also suffer from autonomic neuropathy. Moreover, a substantial number have reduced peripheral arterial perfusion [9]. Deformities such as hammer toes and claw toes are common [10]. These may maintain pressure on the tip of the toe and occurring within additional weight load after relief of the external pressure wound in a neighbouring area exposed to pressure ulceration. Transfer ulceration was defined as a new ulceration. Ulceration is often present under the callus and exposed during debridement. When treatment is inadequate the ulcer deteriorates with risk of invasive infection such as osteomyelitis and/or plantar abscess.

Emphasis has traditionally been placed on conservative measures to relieve external pressure. Shoe correction and a silicon orthosis for elevating the toe, individually adjusted by podiatrists, have previously been used as a standard treatment in our setting. It should be used permanently in order to prevent re-ulceration. However, this method has some negative side effects. Due to neuropathy, disability and/or poor eyesight the patient may fail to place the orthosis correctly and then a new pressure ulcer might develop from the device. The orthosis is, moreover, easily lost.

Alternatively permanent relief of the external pressure can be obtained by surgical correction. A number of procedures with complex intervention on tendons as well as bony structures with quite extensive exposures are available as recently reviewed [11]. Extensive corrective surgery in the neuropathic foot implies however, major risk of tissue damage. Flexor tenotomy is considered as a less invasive procedure. An open surgical procedure has for many years been used for curly toes or hammer toes in children [12]. Recently various minimally traumatizing percutaneous modifications have been adopted for diabetic neuropathic ulcers, and the results reported so far appear satisfactory [10,11,13,14]. The purpose of the present study is to report the results of our modification of the percutaneous flexor tenotomy technique in a series of diabetic patients with ulcers or at high risk of developing ulcers.

Patients and methods

A retrospective study of a consecutive series of toe flexor tenotomies in a 4-year period (January 1, 2006–December 31, 2009) was performed in Steno Diabetes Center. This institution uses an electronic patient record system. The patients were identified in the record system by a search for ICD 10 diagnoses A DE107 and A DE117, in combination with the treatment code V KNHL39. Moreover, the code DL979 + the additional code for type of ulcer were used for patients with ulceration. We identified 38 patients – 30 men and 8 women, mean age 62.8 years (37–91 years) (Table 1). A total of 65 tenotomies were performed by the consultant orthopaedic surgeon (P.E.H). Additional surgery was performed in Copenhagen Wound Healing Center, when required. Sixteen patients had pressure wounds on the tip of the toes, 10 with neuropathic- and 6 with neuroischaemic-ulcers. Classification of diabetes, treatment and co-morbidity was recorded. The presence of peripheral sensory neuropathy was defined as inability to feel a 10 g Semmes–Weinstein monofilament and/or >25 V measured with biothesiometer. The arterial perfusion was evaluated by palpation of the pulses on the foot. In patients with no palpable pulses, strain gauge technique for measuring toe and ankle blood pressure was undertaken. The ulcers were, moreover, classified according to the University of Texas Wound Classification System [16,17]. Time to healing, local complications such as infection, recurrence and transfer ulcers were recorded. Transfer ulceration was defined as a new pressure wound in a neighbouring area exposed to additional weight load after relief of the external pressure on the tip of the toe and occurring within 6 months.

Technique

The indication for tenotomy was ulceration or threatening ulceration of the tip of a toe due to flexion deformity, i.e. hammer toe or claw toe, with a mobile metatarso-phalangeal joint. The surgical procedure was performed with the patient in the supine position. All patients were given local anaesthesia, even in case of severe sensory neuropathy. The surgeon dorsiflexed the toe by the thumb and a transverse stab incision with no 11 pointed blade was performed about 1 cm proximal...
Flexor tenotomy

All patients had follow-up control 1 week after the procedure, and subsequently as required until healing and correction of shoe wear were completed. The majority of the patients suffered other foot ulcers extending the time of the follow up period. Patients treated permanently in this institution had control of their feet at least once a year, in addition to permanent private regular treatment at an authorized chiropodist in the primary care.

Results

The patients suffered diabetes of long duration with heavy co-morbidity (Table 1). Sixteen (42%) of the patients had ulcers lasting for a median of 15 weeks (range 1–48 weeks). Six of these patients had neuro-ischaemic ulcerations (Table 2). The remaining 22 (58%) patients had impending ulceration as evidenced by callosities and/or pressure deformity of the nail. Three patients had osteomyelitis in the toe, which had improved from stage 3B to stage 1B with offloading and antibiotics prior to the operation. Three patients had chronic burned-out Charcot deformity.

The majority of the tenotomies were made on the first and second toe (Table 3). All surgical stab wounds healed without complications; 63 healed within 7–14 days and the last 2 healed in 21 and 30 days. Twenty-five (93%) of the toe ulcers healed with median healing time 21 days (range 7–224 days). One ulcer located on the first toe required additional surgical pressure relief by an osteotomy on the first metatarsal bone and one patient died before healing. None of the patients with neuro-ischaemic ulcers required re-vascularization and the time to healing in neuro-ischaemic ulcers was not different from those with neuropathic ulcerations. None had minor or major amputation.

Thirty-eight patients were followed in the outpatient clinic for a median of 31 months (range 2–48 months). Recurrence of the ulcer was recorded in 3 out of 16 (18%) patients. Healing was obtained again after re-tenotomy in one patient. In another patient with tenotomy of the first toe

| Table 2 Classification just prior to the tenotomy according to the University of Texas Wound Classification System. |
|---|---|---|---|---|
| Stage | Grade 0 | Grade 1 | Grade 2 | Grade 3 |
| A | 37 (57%) | 11 (17%) | 6 (9%) | 2 (3%) |
| B | 9 (14%) | 4 (6%) | 1 (1.5%) | |
| C | 1 (1.5%) | 1 (1.5%) | | |
| D | 2 (3%) | 1 (1.5%) | 2 (3%) | |

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and some rigidity of the metatarso-phalangeal joint, healing was successful after an osteotomy of the first metatarsal bone. One patient died from unrelated reason before new treatment could be performed.

In addition to the three recurrent ulcerations eighteen out of 38 patients (47%) had other types of foot ulcers during the follow-up period. On the ipsilateral foot there were 22 ulcers and on the contralateral foot there was 11. There were 16 toe ulcers, 9 under metatarso-phalangeal joints, 5 on the heels, 1 on the lateral side of the foot, 1 in the pedal arch and 1 on the dorsal side of the foot. One of the ipsilateral ulcers developed 5 months later under the first MP joint after tenotomy of the first toe and could thus be classified as a transfer ulcer. Another patient developed a pressure ulcer under the tip of the 2nd toe seven months after tenotomy of the first toe. In this case transfer pressure might play a role in spite of the late appearance. The other 31 ulcers were typical for the diabetic foot as caused by unauthorized shoe wear, mal-adjustment of shoes and/or insoles, progressive deformities, trauma, bullous diabeticorum, or ischaemia. None of the patients having preventative tenotomy experienced subsequent tip toe ulceration or transfer ulcerations. Prefabricated semi-orthopaedic or bespoke shoes were prescribed or corrected as required and only 16% could employ normal shoes.

**Discussion**

Recently a close relation between occurrence and outcome of diabetic foot ulcers and diabetic co-morbidity has been documented supporting the need for multifactorial treatment by a multidisciplinary team [18]. The patients included in our study were typical with diabetes of long duration with a substantial proportion of co-morbidity and 18 (47%) of the patients had other foot ulcers during the follow up.

Percutaneous flexor tenotomy for diabetic toe ulceration is a relatively new treatment modality. Four earlier studies [11,13–15] have reported satisfactory results in patients with neuropathic ulcers. Two of the studies [14,15] also included patients with peripheral neuropathy for other reasons than diabetes. Various techniques have been employed. Kearney et al. [13] used a transverse incision just proximal to the distal flexor crest at the level of the distal interphalangeal joint cutting only the deep flexor tendon. Schepers et al. [11] and Laborde et al. [15] used a transverse incision at the level of the middle phalanx probably cutting only the deep flexor tendon and Tamir et al. [14] placed the stab wound at the midlevel of the proximal phalanx cutting both flexor tendons. We have abandoned distal transverse incisions due to the sparse soft tissue with risk of poor healing and lesion of the volar plate [14]. Moreover, we prefer to divide both the superficial and deep flexor tendons to obtain maximal relaxation.

Since the results of the different series are very much the same no definite conclusions can at present be drawn as to which technique is preferable. Tenotomy of the flexor tendons does not correct the flexor deformity, but the relaxation obtained relieves adequately the pressure to the tip of the toe. Concerning the first toe the pressure, however, is not always relieved sufficiently by tenotomy due to other biomechanical abnormalities frequently adjacent to tight flexor tendons [19]. Thus two of our patients required an additional osteotomy of the metatarsal bone on the first ray, one for a recurrent ulcer and one for a non-healing ulcer.

Presence of ulceration with local osteomyelitis in the distal phalanx is not a contraindication for tenotomy, but in case of soft tissue infection of the whole toe the procedure should be postponed until infection is controlled. If there is necrosis of the tip of the toe or in case of osteomyelitis involving the distal interphalangeal joint the patient is in our in our setting treated with a (partial) toe amputation. Plantar abscess requires far more extensive and immediate surgical treatment.

Laborde et al. [15] recorded 28% transfer ulcers to neighbour toes. There is no consensus on a definition of a transfer ulcer. We have defined the lesion as a pressure ulcer occurring within 6 months in a neighbouring area obviously exposed to additional load after surgical treatment of a toe. The 6 months period was chosen because the feet in these patients suffer progressive deformities with risk of maladjustment of the insoles and/or the shoes, as well as progressive peripheral neuropathy and ischaemia. This is evidenced by the frequent

<table>
<thead>
<tr>
<th>Table 3 Distribution of tenotomies.</th>
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<tr>
<td>With ulcers 15 (23%) 10 (15%) 2 (3%) 0 0</td>
</tr>
<tr>
<td>Without ulcers 9 (14%) 15 (23%) 7 (11%) 5 (8%) 2 (3%)</td>
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occurrence of ulceration in both feet. One of our patients developed an ulcer on the tip of the 2nd toe seven months after tenotomy of the first toe. In this patient transferred pressure might play a role, but due to the late appearance progressive deformity and/or dysfunction are more likely causes. The complicated problems and definitions of the type of new ulcers in the follow up period are rarely reported in the literature on diabetic foot ulcers.

In the present study 84% of the patients had either corrections of special footwear or had newly prescribed shoe wear, i.e. special roomy diabetic or bespoke shoes, with individually mounted offloading insoles. Special shoes with offloading are of major importance to prevent recurrent foot ulceration, which has been documented in 61% after 3 years [20] and 80% after 2 years [21]. In our series 55% of the patients had new ulcerations including recurrence and transfer ulcers during the follow up of median 31 months in spite of regular control of feet and shoe wear. In the study by Schepers et al. [11] only 50% of the patients received special shoes. In the three other studies [13–15] no information is presented on footwear.

As for healing time after incision, earlier studies have reported a range of 21–56 days [11,13–15], i.e. substantially longer than in our study. The difference might be ascribed to the following factors: the simplicity of our technique, the fact that the stab incision was performed at a site with ample soft tissue, systematic use of pressure relief therapy with therapeutic footwear, close follow-up, antibiotic prophylaxis, adequate final shoe corrections and close attention to glycaemic control and co-morbidity, i.e. the multifactorial approach by the multidisciplinary foot team. It should be mentioned that percutaneous lengthening of the Achilles tendon is also a simple and effective measure to heal recalcitrant neuropathic forefoot plantar ulcers, but in contrast to the flexor toe tenotomy it is often complicated with serious side effect in the form of transfer ulcer to the heel. This procedure is subsequently used only occasionally in our clinic [21,22].

Conclusion

The results in this study on a new modified technique to prevent and treat toe ulcers in patients with diabetes compare favourably with previous literature. The study documents that the patients have severe co-morbidity and also suggest that the procedure can be carried out even in neuroischaemic ulcers. If this can be confirmed in future investigations the indications for flexor tenotomy would expand significantly. So far this simple and effective procedure deserves much attention and controlled investigations.

Conflict of interest

None. There is no conflicts of interest statement.

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[16] Armstrong DG, Lavery LA, Harkless LB. Validation of a diabetic wound classification system. The contribution of


